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SIMILAR CONSUMPTION AND RESPONDING ACROSS SINGLE AND MULTIPLE SOURCES OF DRUG

WARREN K. BICKEL AND GREGORY J. MADDEN

UNIVERSITY OF VERMONT

Two experiments were conducted to assess whether total response output and total consumption would be similar when drugs are available from single and multiple sources of reinforcement, as predicted by behavioral economics. In Experiment 1, cigarette-deprived smokers were exposed to a concurrent-chains schedule in which equal fixed-ratio schedules served as the initial links, and different reinforcer magnitudes (i.e., number of cigarette puffs) were arranged across alternatives. After the session, obtained unit price was calculated and imposed in the next session when a different number of puffs was available according to a single fixed-ratio schedule. Thus, the unit price at which cigarette puffs could be earned was yoked within subjects across the single and concurrent-chains schedules. When plotted as a function of unit price, similar consumption and response rates were usually obtained across these schedules. Experiment 2 addressed a weakness of Experiment 1, namely, that responding was allocated exclusively to the larger reinforcer magnitude in concurrent-chains conditions, and therefore this schedule may have functioned as a single schedule. In Experiment 2, subjects were instructed to alternate responding between the two alternative schedules. Instructions produced approximately equal response allocation between the two alternatives. Again, similar consumption and response rates were observed across the single and instructed concurrent-chains schedules. These findings are discussed in the context of direct effects and behavioral economics perspectives of drug self-administration.

Key words: behavioral economics, drug self-administration, direct effects, satiation, unit price, plunger pull, humans

When drugs may be self-administered under a single schedule of reinforcement, increases in drug dose typically result in either a descending function or an inverted U-shaped function (the dose–response curve) (Katz, 1989). If response rate is taken as a measure of reinforcing efficacy (Griffiths, Brady, & Bradford, 1979), then the descending portion of the dose–response function suggests that high doses have lower reinforcing efficacy than low and moderate doses. One interpretation of the shape of the dose–response function is that large cumulative doses of the self-administered drug have direct response-rate decreasing effects. When these direct effects are operating, the reinforcing effects of the drug, which are assumed to continue to increase (i.e., increase response rate) as drug dose increases, are masked by the drug's direct rate-reducing effects (Skjoldager, Winger, & Woods, 1991, p. 342; Spealman & Goldberg, 1978, p. 324). This interpretation is supported by data collected with concurrent-chains schedules when subjects are allowed to choose between high and low doses. In these experiments, when large cumulative doses of drugs have been ingested and response rates are reduced via direct effects, relative response rates appear to be unaffected and preference is for the relatively larger drug dose (e.g., Johanson, 1975; Johanson & Schuster, 1975).

Another description of the determinants of the inverted U shape of the dose–response function is provided by behavioral economics (Carroll & Bickel, 1998). From a behavioral economic perspective, consumption of any reinforcer (drug or otherwise) declines because of the combined effects of satiation and constraint on access to the reinforcer. Satiation is the reduction in a reinforcer's effectiveness that follows from the continued presentation of the reinforcer (Catania, 1968; see Pearce, 1989, for an economic definition). Constraint refers to decreased ability to acquire a reinforcer via, for example, price increases. According to a behavioral economic account, response rates increase on the ascending limb of the dose–response function

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Reprints may be obtained from Warren K. Bickel, Human Behavioral Pharmacology Laboratory, Department of Psychiatry, 38 Fletcher Place, Burlington, Vermont 05401-1419 (E-mail: warren.bickel@uvm.edu).

because each dose increase represents a decrease in the price at which the drug is available (i.e., a decrease in constraint on drug access). Here, the price of a drug is given by its unit price: effort expended in obtaining the drug divided by drug dose (e.g., Bickel, DeGrandpre, Higgins, & Hughes, 1990; Hursh, Raslear, Shurtleff, Bauman, & Simmons, 1988). Because insufficient amounts of drug may be obtained along the ascending limb to produce satiety, price is the primary determinant of response rate along this portion of the dose–response curve. Conversely, response rates decline on the descending limb of the dose–response curve because as the magnitude of a drug reinforcer is increased, the constraint imposed on drug access is decreased and the level of drug intake necessary to produce satiety is reached after fewer reinforcer deliveries (Carroll & Bickel, 1998). Preference for the relatively larger drug dose in choice experiments is predicted by behavioral economics (and the economic demand law; see, e.g., Samuelson & Nordhaus, 1985) because the larger drug dose is available at a relatively lower unit price. Finally, consistent with a behavioral economic interpretation, the function describing the effects of appetitive reinforcer magnitude on response rates (the food ''dose–response'' function) is also an inverted U-shaped function (Goldberg, 1973). Although the same functional relation between food magnitude and drug dose does not guarantee that both may be explained by equivalent processes, this evidence is supportive of the behavioral economic interpretation.

Distinguishing the relative contribution of direct effects, satiation, and economic constraint on drug self-administration is difficult because (a) the response-rate increasing effects of increasing reinforcer magnitude (direct effects account) are similar to the rate-increasing effects predicted when constraint on access to a reinforcer is decreased (behavioral economic account), (b) the response-rate reductions produced by direct effects of large cumulative doses of drug are similar to what would be expected from the effects of drug satiety (behavioral economic account), and (c) both accounts predict preference for larger drug doses in choice situations. Until empirical evidence provides definitive support for only one of these interpretations, we are forced to evaluate the relative utility of each by assessing their capacity to make novel and accurate predictions about drug self-administration (cf. Williams, 1984). Some of these predictions may be consistent with only one account, and the results of studies assessing these would offer empirical support for only one theoretical account. Other predictions may arise easily from only one account, but can be theoretically consistent with both. These predictions would provide empirical support for both accounts, but argue for one perspective because it generates more research than the other.

A novel prediction arising from a behavioral economic account of the dose–response curve (and one not made by a direct effects account) is that total response output and total consumption of any reinforcer will be equivalent at a given level of constraint regardless of the number of sources from which that reinforcer may be acquired. Total response output describes the sum of all instrumental responses emitted per session on one or more than one schedule of reinforcement; it does not describe the relative distribution of behavior when there is more than one source of reinforcement. Likewise, total consumption is the sum of all reinforcers obtained in a session (from all relevant schedules of reinforcement) rather than a measure of the distribution of reinforcers obtained from more than one source. When considering levels of total response output and total consumption of a reinforcer, a behavioral economic account makes no distinction between situations in which reinforcers may be obtained from one or more than one alternative. Instead, constraint is determined by the average price at which the reinforcer is obtained, and satiation results as a function of total intake across the two sources of the same reinforcer. Thus, the behavioral economic interpretation suggests that the effects of single and multiple sources of drug reinforcement on total response output and total drug consumption are similar (i.e., response output and drug consumption under single schedules should approximately equal the sum of responses allocated to, and the sum of drugs consumed from, more than one source of drug reinforcement). To our knowledge the direct effects interpretation has not addressed these issues.

To test these behavioral economic predictions, a common metric is required to insure that a common level of constraint is imposed across conditions in which one or more than one schedule of drug reinforcement is arranged. Such a metric may be afforded by unit price, which was suggested for use in the study of drug reinforcement as early as 1973 (Balster & Schuster, 1973). When two sources of the same drug are concurrently available,

$$\text{unit price} = \frac{B_1 + B_2}{(R_1A_1) + (R_2A_2)}, \quad (1)$$

where B represents the number of responses per session on the two alternatives, R is the number of reinforcers obtained on these alternatives, and A represents the two arranged reinforcer amounts (or drug doses). Because Equation 1 defines unit price by simply totaling costs and benefits across both schedules of reinforcement, a common metric is provided for comparing behavior maintained by one or more than one schedule of reinforcement.

The present experiments were conducted with human cigarette smokers to assess the equivalence of total drug consumption and total response output when drug reinforcers could be obtained from one or more than one schedule of reinforcement. In the first experiment, a yoking procedure was used in which unit prices obtained under two-alternative concurrent-chains conditions were used to set the unit price at which cigarette puffs could be obtained from a single schedule of reinforcement. To date, overall response rates and levels of drug intake maintained when drugs may be obtained from one and more than one schedule of drug reinforcement have not been compared within a subject.

EXPERIMENT 1

In this experiment, each participant was provided with various reinforcer magnitudes (different number of cigarette puffs) under a single schedule arrangement to identify those magnitudes that fell along the descending limb of each subject's dose–response curve. The magnitudes that fell on the descending limb were employed in the next portion of this experiment. Next, concurrent-chains schedules of response-contingent cigarette puffs were arranged with two different puff amounts across the alternatives. After the session, the obtained unit price for the concurrent-chains schedule was determined per Equation 1. This obtained unit price was then imposed in the next single-schedule session with a reinforcer magnitude different from the one that was employed in the preceding concurrent-chains session. If unit price and satiation combine to determined intake at low unit prices, and unit price determines consumption when drug intake is constrained (and satiation is not a factor), then total consumption should be similar irrespective of whether a drug is available via one or two sources.

Method

Participants. Four women (S1 through S4) and 2 men (S5 and S6) (mean age = 32.3 years; range, 21 to 48 years) participated. ''Healthy smokers'' were recruited via newspaper advertisements that indicated compensation of $500 or more. They provided informed consent before participating (see the Appendix). Subjects reported smoking 20 or more cigarettes per day (M = 27), were judged to be in good physical and psychological health on the basis of self-report, and obtained scores of 5 or higher (M = 6.5) on the Fagerström Tolerance Questionnaire, a self-report measure of nicotine dependence (Fagerström & Schneider, 1989). Before beginning the experiment, subjects provided breath samples that were measured for baseline carbon monoxide (CO) level (expired air CO is a direct function of prior smoking; Henningfield, Stitzer, & Griffiths, 1980). All subjects had baseline CO levels of at least 18 ppm (M = 32.2 ppm). Two subjects (S3 and S5) had participated previously in smoking experiments conducted in our laboratory. Subjects were compensated with $17.50 per session to be paid at the end of the experiment, an additional $17.50 per session as a bonus if they completed the study (see the Appendix for further details on payment).

Apparatus. Subjects worked alone while sitting in a small room containing a response console (61 cm by 30 cm by 46.5 cm) equipped with three Lindsley plungers (Gerbrands G6310) centered from left to right on the face of the console (20 cm between the plungers). A pull of approximately 6 N was

required for each response (see Bickel et al., 1990, for additional details). Above the console was a monochrome computer monitor and a computer (Apple II GS®) that recorded data and controlled events that occurred during the session. A volumetric low-pressure transducer (Grass Instruments, Model PT5) was modified to measure the volume of cigarette smoke inhaled through a plastic cigarette holder fitted to the filter end of a standard cigarette. Each room was also equipped with a radio and a daily newspaper. A large selection of magazines was available in an adjacent room.

General procedure. Subjects were required to abstain from smoking for 5 to 6 hr before each session in order to provide a breath sample with a CO level at or below half that of their preexperiment baseline (see the Appendix for other requirements). In those instances in which subjects did not pass this presession CO test, the session was rescheduled. Subjects took one uniform puff on their preferred brand of cigarette 30 min before the session (all cigarettes were provided by the experimenter). This presession puff equated the time since last exposure to cigarettes across participants (Henningfield & Griffiths, 1981). The 3-hr sessions were scheduled 5 days per week.

Before each session, the experimenter provided the subjects with a written copy of the following instructions:

> In this study you can earn cigarette puffs by responding on one of the three plungers. In some sessions, puffs can be earned by responding on either of two plungers; for other sessions, puffs will be available on one plunger. When you earn puffs, the counter on the computer screen will increase by one. Prior to beginning each day, you will be provided with this sheet which will tell you how many responses you must make on a plunger to get puffs. When you have earned puffs, you have 90 seconds per puff to take them. During this time, you will be instructed to inhale, hold for 5 seconds, and exhale the smoke for each puff, with 25 seconds between puffs. The computer screen will count down the time you have to take puffs and will tell you when you may respond on the lever(s) again by displaying ''You may respond now.''

The instruction sheet also specified the number of responses required to earn puffs and the number of puffs earned by completing the response requirement. Schedule parameters remained in effect for one session each. Similar and analogous procedures have been demonstrated to produce replicable within-subject patterns of behavior across a range of unit prices in human (e.g., Bickel, DeGrandpre, Hughes, & Higgins, 1991; Bickel, Hughes, DeGrandpre, Higgins, & Rizutto, 1992) and nonhuman subjects (e.g., Raslear, Bauman, Hursh, Shurtleff, & Simmons, 1988).

Cigarette-puff training. Subjects completed up to two 3-hr training sessions in which they learned to smoke according to a standard cigarette-puffing procedure (Zacny, Stitzer, Brown, Yingling, & Griffiths, 1987) during a smoking interval. The duration of the smoking interval was 90 s per puff. When three cigarette puffs had been earned by completing a fixed-ratio (FR) 3 requirement on the center plunger, the on-screen message ''puff now'' was presented. Subjects then lit a cigarette without inhaling, placed the lit cigarette in the plastic holder connected by polyurethane tubing to the puff-volume sensor, and inhaled until approximately 70 cc of smoke had been drawn. To facilitate subjects' inhaling an average of 70 cc of smoke, the cumulative volume of smoke inhaled (in cubic centimeters) was presented on the screen while the smoker took each puff, and the computer produced a brief tone when 60 cc had been inhaled; subjects were instructed to stop inhaling when they heard this tone. Following smoke inhalation, subjects held the smoke in their lungs until the computer produced a pair of tones 5 s after the first. A 25-s interval was initiated at smoke exhalation, and at the end of this interval a second on-screen prompt to ''puff now'' informed subjects when they could take their next puff. This process was repeated until subjects had taken three puffs. Responses on the plungers had no programmed consequences during the smoking interval. A series of three tones and the message ''You may respond now'' signaled the end of the smoking interval. If at the end of any session the average puff volume deviated from 70 cc by more than 5 cc or if the subject failed to smoke all earned puffs during the allocated smoking intervals, the conditions were repeated during the next scheduled session.

Subjects worked alone during all sessions following the training session. The doors separating the subjects and the experimenter were equipped with one-way mirrors through which subjects were occasionally monitored for compliance with the standard puffing procedure. Subjects were instructed to remain in their rooms at all times except to use the bathroom or to get additional reading material. During the sessions, all subjects read the available magazines and newspapers and several listened to the radio.

Adjusting-dose sessions. In the sessions following training, cigarette puffs were available according to an FR 400 schedule on the center plunger. The number of puffs (2, 4, 6, 8, or 12) earned by completing this schedule was changed across sessions. Puff amounts were changed in a mixed sequence with one session at each puff amount until three values were found that produced decreases in individual subjects' response rates as puff amounts increased. These sessions were designed to insure that the doses employed were inversely related to response rate. From the results of this condition, reinforcer magnitudes were selected so the number of puffs earned under single-schedule conditions would be different from the numbers of puffs arranged in sessions in which more than one source of cigarette puffs was available. We viewed this as a stringent test of behavioral economic predictions concerning total response output and total consumption under single and more-than-one alternative conditions.

Concurrent-chains sessions. In the first and all subsequent odd-numbered sessions following the training and adjusting-dose sessions, cigarette puffs were available according to two concurrently available FR schedules, one programmed on the left plunger and the other on the right. Center plunger responses were likewise without consequence and were unrecorded during concurrent-chains sessions. Reinforcers under these schedules were, respectively, the lowest and highest number of puffs that had been identified as falling on the descending dose–response function in the preceding adjusting-dose condition. (During even-numbered sessions, cigarette puffs were available according to a single FR schedule [see next section below]. The number of puffs used as the reinforcer in this session was the intermediate value identified in the preceding condition.) When responding had begun on one of the plungers in the concurrent schedule, responses on the other plunger had no scheduled outcome and were not recorded; thus, this constitutes a concurrent-chains procedure. Within a session, the FR requirement was identical across alternatives, while the number of puffs arranged on each alternative was different (e.g., FR 100 for two puffs on the left plunger and FR 100 for eight puffs on the right). Table 1 shows the FR values to which subjects were exposed across concurrent-chains and single-schedule sessions. The different FR requirements, manipulated across sessions, were presented in a random order (without replacement) that was varied across subjects. When sessions had been completed under all FR requirements in both the concurrent-chains and single-schedule sessions, a second such sequence of FR requirements and schedule types was carried out. The plunger on which the larger number of puffs was arranged was counterbalanced across replications.

Single-schedule sessions. A single-schedule session was conducted for the next session following a concurrent-chains schedule session. During single-schedule sessions, subjects could obtain cigarette puffs by completing an FR schedule requirement on the center plunger; responses on the other plungers had no programmed consequence and were not recorded. The FR values in single-schedule sessions were set by yoking the unit price of puffs in these sessions to those obtained in the immediately preceding concurrent-chains session. Unit prices of puffs obtained in the latter sessions were calculated according to Equation 1. One single-schedule session was completed for each concurrent-chains session conducted.

Statistical methods. The relation between consumption (C) and unit price (P) was modeled using the logarithmic version of the nonlinear demand equation proposed by Hursh et al. (1988):

$$\ln C = \ln L + b \ln P - aP, \qquad (2)$$

where L is the initial consumption at unit price 1.0, and b and a are related to the initial slope and acceleration in slope of the demand curve, respectively. Individual-subject parameter estimates were obtained through

Table 1

Order (left to right) of fixed-ratio values presented (and unit prices obtained at those values) in the concurrent-chains FR FR and single FR schedule sessions that alternated with each other in Experiment 1. (See text for the way in which single FR values were yoked to unit price obtained in the preceding concurrent-chains session.) When the sequence of FR schedules was completed, it was repeated. Two unit prices are shown for some concurrent-chains schedule values because the distribution of responses differed across replications. For 2 subjects (S2 and S4) the FR value in the single-schedule session was changed in the second sequence of sessions in order to more closely yoke unit price to that obtained under the comparison concurrent-chains schedule session.[a]

Subject	Schedule type	Fixed-ratio values (obtained unit prices[b])						
S1	Concurrent	8 (0.67)	60 (5)	1,200 (100)	2,000 (167)	4,800 (400)	36,000 (3,000)	
	Single	5 (0.62)	40 (5)	800 (100)	1,333 (167)	3,200 (400)	24,000 (3,000)	
S2	Concurrent	8 (1.0, 1.1)	60 (7.5, 8.6)	1,200 (150)	2,000 (250)	8,000 (1,000)	9,600 (1,200)	16,000 (2,000)
	Single	4 (1.0)	30 (7.5)	600 (150)	1,000 (250)	4,000 (1,000)	4,800 (1,200)	8,000 (2,000)
			34 (8.5)					
S3	Concurrent	8 (1)	60 (7.5)	1,200 (150)	2,000 (250)	8,000 (1,000)		
	Single	4 (1)	30 (7.5)	600 (150)	1,000 (250)	4,000 (1,000)		
S4	Concurrent	8 (0.7, 0.80)	60 (5, 6)	200 (100)	2,000 (167)	1,200 (600)	9,600 (800)	36,000 (3,000)
	Single	5 (0.6)	40 (5)	800 (100)	1,333 (167)	4,800 (600)	6,400 (800)	24,000 (3,000)
		6 (0.7)	48 (6)					
S5	Concurrent	8 (1)	60 (7.5)	1,200 (150)	2,000 (250)	2,400 (300)	3,200 (400)	6,400 (800)
	Single	4 (1)	30 (7.5)	600 (150)	1,000 (250)	1,200 (300)	1,600 (400)	3,200 (800)
S6	Concurrent	8 (1, 1.1)	60 (7.5)	2,000 (250)	8,000 (1,000)	48,000 (6,000)		
	Single	4 (1)	30 (7.5)	1,000 (250)	4,000 (1,000)	24,000 (6,000)		

[a] This change was accidentally omitted for Subject S6 at the lowest unit price.

[b] Number of puffs available in the concurrent-chains schedule sessions were 4 and 12 for S1; 2 and 8 for S2, S3, S5, and S6; and 2 and 12 for S4. Number of puffs available in the single FR schedule was 8 for S1 and S4 and 4 for S2, S3, S5, and S6.

standard linear regression techniques (SAS® statistical software, PROC REG). The proportion of variance (R^2) accounted for by Equation 2 was calculated for each demand curve. For several subjects, very high unit prices completely suppressed consumption. In these cases, one puff was substituted for zero puffs for the purposes of deriving parameter estimates, because zero is undefined in logarithmic coordinates.

Results

Figure 1 shows for individual subjects the number of responses per session at several reinforcer magnitudes arranged at FR 400. For all subjects, response rates tended to decrease as a function of increasing numbers of cigarette puffs (dose). For S1, response output in the two-puff (2,200 responses) and four-puff (2,400 responses) sessions suggested a bitonic dose–response function, but for the remaining subjects a decreasing function was obtained. Prior research conducted in our laboratory suggests that had fewer puffs been arranged (e.g., one puff), response rates would have been lower than rates maintained at two or four puffs (e.g., Bickel et al., 1991). The shaded bars in Figure 1 show the puff amounts arranged in the subsequent single and concurrent-chains reinforcement sessions; thus, the reinforcer magnitudes subsequently employed fell along the declining portion of individual subjects' dose–response curves.

Figure 2 shows for individual subjects that with one exception (S4, unit price = 600) during concurrent-schedule sessions, nearly all responses were made on the alternative with the larger number of puffs available. Because different puff amounts were arranged according to the same FR schedule across concurrent-chains alternatives, the alternative with the larger reinforcer magnitude also had a lower unit price. Thus, in a choice situation, subjects consistently preferred the larger dose and the alternative at which puffs could be obtained at a lower unit price.

The left column of graphs in Figure 3 shows the number of cigarette puffs consumed per session at each unit price and demand curves fit to these data in the separate single and concurrent-chains conditions

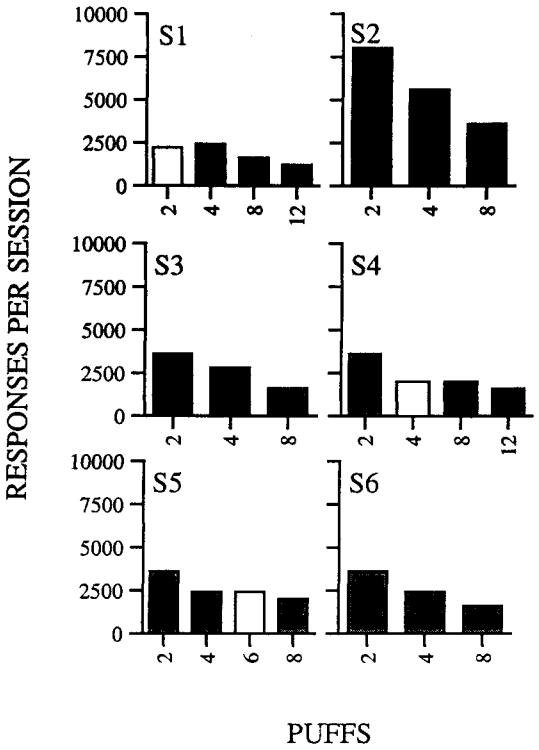

Fig. 1. Number of responses individual subjects made per 3-hr session as a function of the number of puffs per reinforcer delivery at FR 400. Subjects completed a single session at each puff amount. Shaded bars show the reinforcer amounts employed in subsequent single and concurrent-chains schedule sessions.

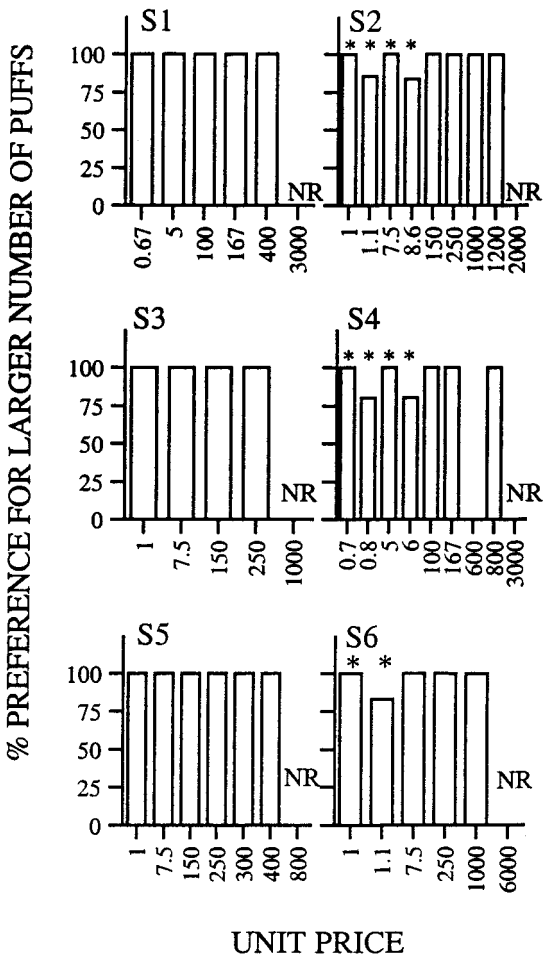

Fig. 2. Percentage of reinforcers obtained from the concurrent schedule alternative with the larger number of puffs available at different unit prices. Asterisks indicate those unit prices at which a single session was conducted. For the remaining prices, data are averaged across two sessions. For each subject, no responding was maintained (NR) at the highest FR requirement. At a unit price of 600, S4 showed exclusive preference for the alternative with the relatively smaller number of puffs.

(note the logarithmic coordinates). Parameters of the demand curves and proportion of variance accounted for (R^2) are presented in Table 2.

For all subjects, and in both schedule conditions, demand for cigarette puffs was a positively decelerating function of price increases when plotted on logarithmic coordinates. The predicted intercept of the demand curves at unit price 1 (L in Table 2) was consistently higher in the concurrent-chains schedule sessions. However, except for S4 and S5, these differences were within one round of puffs earned from the concurrent-chains alternative with the larger number of puffs available. Visual inspection of the left panels of Figure 3 reveals considerable overlap across the single and concurrent-chains conditions in the number of cigarette puffs smoked at each unit price. The similarity of the demand curves plotted through these data reflect this overlap. Exceptions may be noted in S4's and S5's cigarette consumption at low and high unit prices. Both subjects smoked more puffs in the concurrent-chains condition at low unit prices and tended to smoke more puffs in the single-schedule condition at high unit prices. For S4, fewer puffs were consumed in some of the concurrent-chains sessions at unit prices of 600 and 800, but this subject failed to smoke in the single or concurrent-chains sessions at the highest unit price (3,000). S5 failed to smoke in about half of the concurrent-chains sessions

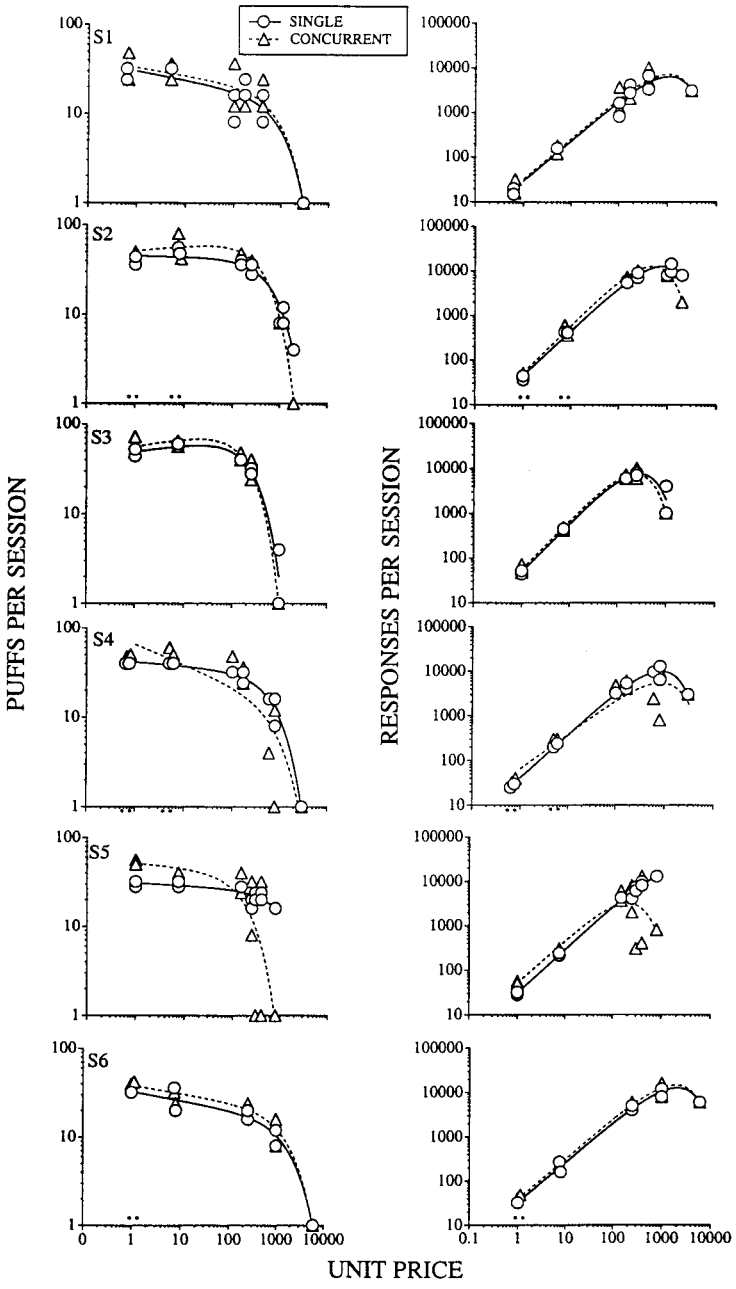

Fig. 3. Number of cigarette puffs smoked (left column) and the number of responses made (right column) per session in the single and concurrent schedule sessions. Individual data points correspond to individual sessions conducted at each unit price. Separate demand curves are fit to each schedule type using Equation 2. For those sessions in which no cigarette puffs were consumed, data are shown as 1.0 because zero is undefined in logarithmic coordinates. Sessions in which one single and concurrent-chains schedule session (instead of two) was conducted at a given unit price are identified with asterisks on the *x* axis.

Table 2

Parameters of individual subjects' demand curves in single and concurrent schedules derived using Equation 2. L is an estimate of consumption at unit price 1.0, and b and a are related to the initial slope and acceleration of the demand curve, respectively. Variance accounted for by the fitted demand curves is provided by R^2.

Subject	Condition	L	b	a	R^2
S1	Single	29.9	−0.107	−0.0008	0.88
	Concurrent	32.8	−0.095	−0.0009	0.92
S2	Single	45.2	−0.010	−0.0012	0.96
	Concurrent	51.2	0.054	−0.0021	0.98
S3	Single	49.1	0.077	−0.0037	0.97
	Concurrent	56.0	0.093	−0.0046	0.99
S4	Single	41.4	−0.045	−0.0011	0.97
	Concurrent	65.3	−0.230	−0.0009	0.86
S5	Single	30.8	−0.030	−0.0006	0.71
	Concurrent	51.4	−0.048	−0.0047	0.63
S6	Single	32.6	−0.101	−0.0004	0.98
	Concurrent	38.5	−0.093	−0.0005	0.98

conducted at unit prices higher than 250. However, in the sessions in which he did smoke at these unit prices, consumption was higher than in the comparable single-schedule sessions.

The right column of graphs in Figure 3 shows the number of responses made per session at each unit price in the single- and concurrent-schedule conditions (note the logarithmic coordinates). Separate functions were fit to single and concurrent-chains schedule data using a variant of Equation 2 (1 was added to the initial slope parameter, b, derived from demand curves). The similarities and differences observed in individual subjects' cigarette demand curves are likewise apparent in these response output functions.

Discussion

The results of this experiment suggest that cigarette consumption was not systematically affected by schedule type. Considerable overlap was observed in the number of puffs consumed per session at a given unit price in single- and concurrent-schedule conditions, and differences between consumption levels predicted by demand curves from these conditions were infrequently observed. When differences in rates of cigarette consumption were detected, they were observed at the lower and upper ranges of unit prices employed.

Income constraints may provide an explanation of the differences observed at high unit prices. In concurrent-schedule sessions, a relatively larger FR requirement was imposed on the acquisition of puffs from either concurrently available schedule than was required during single-schedule sessions at the same unit price. As unit prices increased during concurrent-schedule sessions, an increasing proportion of session time tended to be spent making the instrumental response. At the highest unit prices employed, concurrent-schedule FR values were so high that subjects may not have had sufficient time (i.e., income) to complete the response requirement in the 3-hr session. By contrast, in single-schedule sessions at the same unit price, the FR requirement was lower (because fewer puffs were earned) and could be more easily met within the temporal constraints of the session. Had the duration of the present experiment been longer, or if instrumental response rates had been higher, the puff-intake rate differences obtained between single and concurrent conditions may not have been observed.

Although the puff amounts employed with each subject fell along the descending limb of the dose–response curve and were of different magnitudes across the single and concurrent-chains schedules, total intake and response output under single and concurrent schedules were usually similar at the same unit price across subjects. These data suggest that unit price plays an important role in determining total response output and consumption in both single and concurrent-chains schedules, even when different reinforcer magnitudes are used. Moreover, these data suggest that unit price may be applicable to multioperant environments in which the same reinforcer is available via multiple sources.

The latter conclusions regarding the applicability to concurrent reinforcement (choice) contexts may need to be qualified, however, because of a shortcoming of this experiment, namely, that preference during concurrent-chains sessions was nearly always directed at the alternative that provided more cigarette puffs per administration. This exclusive preference may have functionally reduced the concurrent-chains schedule to a single-schedule arrangement. Thus, similar results across single and concurrent-chains schedules would be expected. The next experiment was designed to address this shortcoming.

Table 3

Order (left to right) of fixed-ratio values presented (and unit prices obtained at those values) in the concurrent-chains FR FR and single FR schedule sessions that alternated with each other in Experiment 2. (See text for the way in which single FR values were yoked to unit price obtained in the preceding concurrent-chains session.) When the sequence of FR schedules was completed, it was repeated. Two unit prices are shown for some concurrent-chains schedule values because the distribution of responses differed across replications. For 1 subject (S7), the FR value in the single-schedule session was changed in the second sequence of sessions in order to yoke more closely unit price to that obtained under the comparison concurrent-chains schedule session.

Subject	Schedule type	Fixed-ratio schedules (unit prices[a])					
S7	Concurrent	8 (1.6, 1.7)	50 (10, 10.5)	1,200 (240)	2,400 (480)	9,600 (1,920)	20,000 (10,000)
	Single	6 (1.5)	42 (10.5)	960 (240)	1,920 (480)	7,680 (1,920)	40,000 (10,000)
		7 (1.7)					
S8	Concurrent	8 (1.6, 1.7)	200 (40)	1,200 (240)	2,400 (480)	4,000 (800)	4,000 (2,000)
	Single	6 (1.5)	160 (40)	960 (240)	1,920 (480)	3,200 (800)	8,000 (2,000)
S9	Concurrent	12 (1.5)	80 (10, 10.8)	640 (80)	3,840 (480)	9,600 (2,400)	
	Single	12 (1.5)	80 (10.8)	640 (80)	3,840 (480)	19,200 (2,400)	

[a] Number of puffs available in the concurrent-chains schedule sessions were 2 and 8 for S7 and S8 and 4 and 12 for S9. Number of puffs available in the single FR schedule was 4 for S7 and S8 and 8 for S9.

EXPERIMENT 2

In this experiment, we eliminated an exclusive response distribution to the larger reinforcer magnitude during concurrent-chains sessions by instructing subjects to alternate responding between the two available schedules. If subjects complied with these instructions, then the two alternatives would be sampled approximately the same number of times. Although these instructions rendered the concurrent-chains schedule something other than a choice situation, this procedure allowed us to determine whether the same profile of results would be obtained when responses were distributed across both components of the concurrent-chains schedule. If, on one hand, exclusive responding on one concurrent-schedule alternative had been responsible for the similar intake and response rates under the two schedules in Experiment 1, then in Experiment 2, differences by schedule type should be observed. If, on the other hand, the results of Experiment 1 were independent of response allocation, then in Experiment 2, differences by schedule type should not be observed. Other than the use of the instruction to alternate responding to the two components of the concurrent-chains schedule, procedures employed in this study were similar to those used in Experiment 1.

Method

Participants and apparatus. Three experimentally naive smokers, 2 men (S7 and S8) and 1 woman (S9), with a mean age of 33.3 years (range, 31 to 35) worked at the same response console described in Experiment 1. Subjects reported smoking 20 or more cigarettes per day ($M = 20.8$) and obtained scores of 5 or higher on the Fagerström's Tolerance Questionnaire ($M = 6.3$). All subjects had baseline CO levels of at least 24 ppm ($M = 28.3$). Other details were as in Experiment 1.

Procedure. The procedures described in Experiment 1 were employed with one exception: Before each concurrent-chains schedule session, subjects were instructed on which alternative to begin responding (the alternative with the higher unit price per puff) and were directed to switch between alternatives after they had earned puffs. Because this procedure is atypical of concurrent-chains procedures, we will refer to it as an "instructed" concurrent-chains procedure.

As in Experiment 1, puff amounts employed in the two types of sessions were determined for each subject by finding three amounts that fell along the descending portion of each subject's dose–response curve. Table 3 shows the FR values to which subjects were exposed across single FR and instructed concurrent-chains schedule sessions. As be-

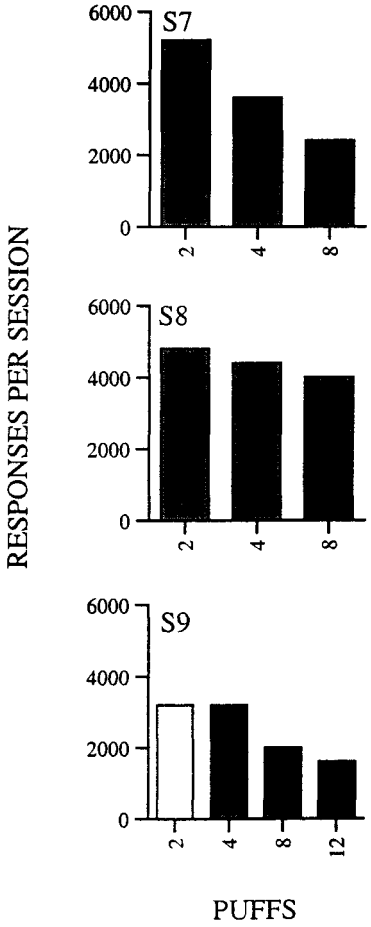

Fig. 4. Number of responses individual subjects made per 3-hr session in Experiment 2 as a function of the number of puffs per reinforcer delivery at FR 400. Data were collected in the sessions that preceded comparisons between single and concurrent-chains schedule performances. Subjects completed a single session at each puff amount.

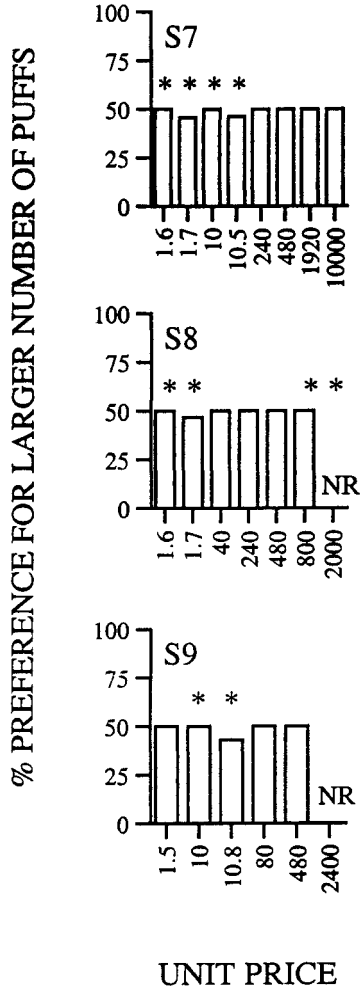

Fig. 5. Percentage of reinforcers in Experiment 2 obtained from the instructed concurrent-chains schedule alternative with the larger number of puffs available. Asterisks indicate those unit prices at which a single session was conducted. For the remaining prices, data are averaged across two sessions. For S8 and S9, no responses were maintained (NR) at the highest FR requirement.

fore, unit prices in single FR sessions were yoked to the unit price obtained in the preceding instructed concurrent-chains session. Subjects were exposed to two of each type of session at each unit price.

Results

Figure 4 shows that each subject's response rates under FR 400 conditions generally decreased with increases in reinforcer magnitude (i.e., puff amount). Thus, as in Experiment 1, the reinforcer magnitudes employed fell on the descending limb of the inverted U-shaped dose–response curve. Figure 5 illustrates that, without exception, subjects complied with the instruction to switch between alternatives across trials. Asymmetric response allocations occasionally occurred in those sessions in which subjects completed an odd number of trials.

The left column of graphs in Figure 6 shows the number of cigarette puffs consumed per session in single and instructed concurrent-chains schedule sessions. Demand curves were fit to these data using Equation 2, and parameters of individual subjects' demand curves are presented in Table

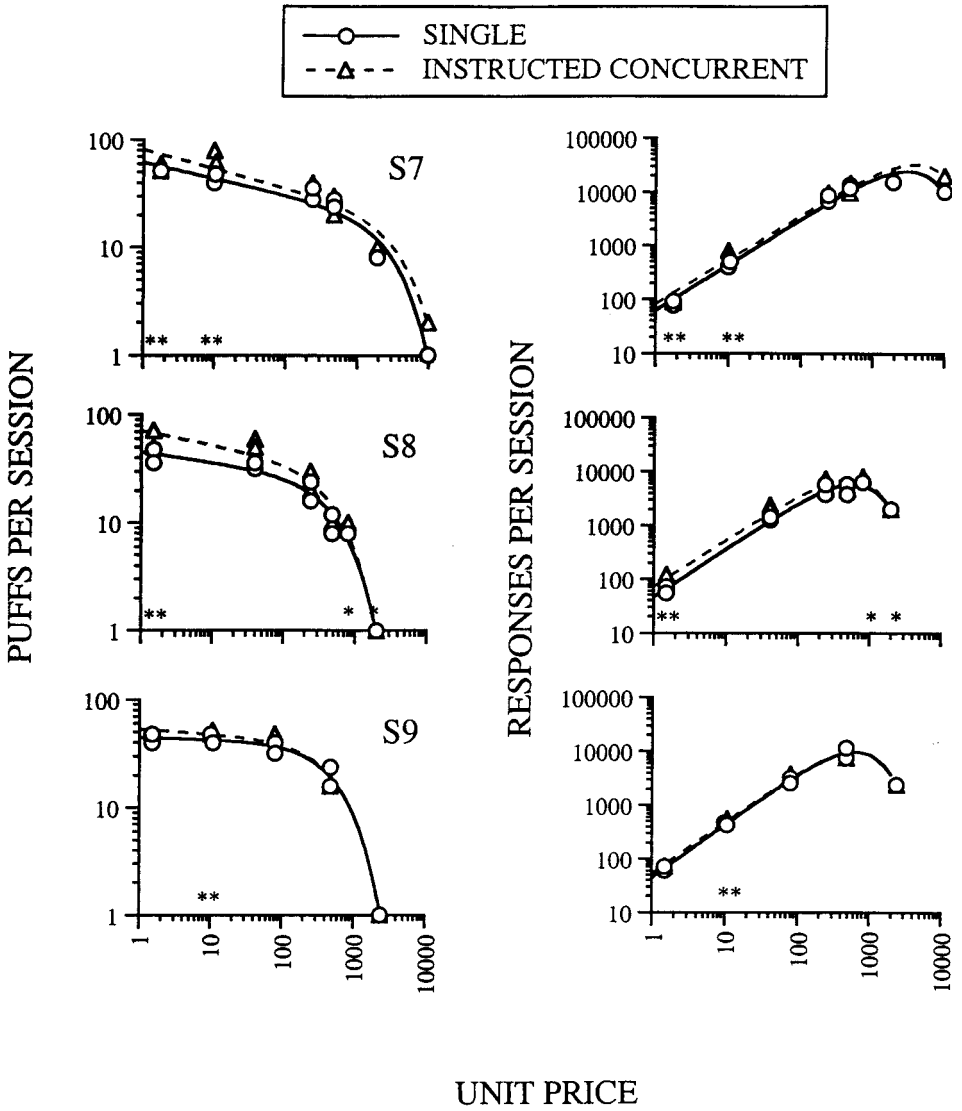

Fig. 6. Number of cigarette puffs smoked (left column) and the number of responses made (right column) per session in the single and instructed concurrent-chains schedule sessions of Experiment 2. Individual data points correspond to individual sessions conducted at each unit price. Separate demand curves are fit to each schedule type using Equation 2. For those sessions in which no cigarette puffs were consumed, data are shown as 1.0 because zero is undefined in logarithmic coordinates. Sessions in which one single and instructed concurrent-chains schedule session (instead of two) was conducted at a given unit price are identified with asterisks on the *x* axis.

4. Consistent with Experiment 1, the shape of the demand curves was positively decelerated. Also consistent with Experiment 1, predicted consumption at a unit price of 1 (L in Equation 2) was higher in concurrent-schedule sessions. However, no consistent differences were observed in actual cigarette consumption rates at a unit price of 1 across the two types of schedules. Likewise, across the range of unit prices examined, no systematic differences in rates of cigarette consumption were observed across single and instructed concurrent-chains schedule sessions. These similarities are reflected in the response-output data and functions shown in the right column of graphs in Figure 6.

Table 4

Parameters of individual subjects' demand curves in single and instructed concurrent-chains schedules derived using Equation 2. Parameters of the demand curves are as in Table 2.

Subject	Condition	L	b	a	R^2
S7	Single	62.0	−0.150	−0.0003	0.98
	Concurrent	81.3	−0.176	−0.0002	0.95
S8	Single	45.4	−0.094	−0.0016	0.97
	Concurrent	71.6	−0.130	−0.0017	0.95
S9	Single	44.8	−0.017	−0.0015	0.99
	Concurrent	53.5	−0.044	−0.0015	0.99

Discussion

Subjects complied with instructions to alternate between the two plungers in the concurrent schedule, which resulted in an approximately equal distribution of responding to the two alternatives. This finding demonstrates that instructions can surmount control exerted by larger reinforcer magnitudes (i.e., subjects followed instructions to alternate between larger and smaller numbers of puffs) and extends the role of instruction in schedule performance (Baron, Kaufman, & Stauber, 1969; Galizio, 1979). Although one component of our subjects' behavior was under instructional control, it is unlikely that instructions was the sole determining factor in responding. That is, as unit price increased consumption decreased; response rates increased in a fashion consistent with the results of Experiment 1 and other behavioral economic studies (e.g., Bickel et al., 1990, 1991; Bickel, DeGrandpre, Higgins, Hughes, & Badger, 1995; DeGrandpre, Bickel, Hughes, Layng, & Badger, 1993). Thus the results demonstrate that the behavior was sensitive to unit price manipulations.

It is important to note that in this experiment response allocation was approximately equal across the two schedule alternatives and puff consumption was highly similar across single and instructed concurrent-chains schedules. These data are consistent with the results of Experiment 1 showing similar consumption at equal unit prices across single and concurrent-chains schedules. The consistency of results across experiments argues *against* the alternative explanation of Experiment 1, namely, that exclusive allocation of responding to one alternative functionally reduced the concurrent-chains schedule to a single schedule.

GENERAL DISCUSSION

These studies found (a) that similar intake and response rates were obtained when the same unit price was arranged under single and concurrent-chains FR schedules of cigarette presentation, and (b) that this effect was independent of whether responding under the concurrent schedule was exclusive to one alternative or was equally allocated between alternatives.

These findings suggest a commonality between concurrent and single schedules of reinforcement that, to our knowledge, has not been recognized previously—namely, that unit price determines total consumption across both single and concurrent-chains FR schedules of reinforcement, at least when identical reinforcers are used across the concurrent-schedule alternatives. This consistency was observed whether responding was allocated to one or was distributed equally between alternatives (Logue & Chavarro, 1987). This suggests that unit price is a feature of concurrent schedules that determines level of intake and response rate independent of variables that affect the allocation of behavior among alternatives. Unit price may play a role in determining the absolute level of reinforcement through the opposing effects of cost and satiation (i.e., lowering unit price decreases cost, thereby increasing the likelihood of responding, and increases the effects of satiation, thereby decreasing the likelihood of responding). Unit price may be a useful concept for those approaches to choice that wish to address absolute consumption and total response rates in addition to relative consumption and responding.

These studies constitute a stringent test of the concept of unit price and demonstrate its relevance to understanding total intake in concurrent schedules of reinforcement when the same commodity is arranged on both alternatives. Unit price previously has been demonstrated to determine level of consumption with single schedules of reinforcement in a variety of research reports (Bickel et al., 1990, 1991; Carroll, 1991; DeGrandpre et al., 1993; Hursh et al., 1988; Winger, 1993; Winger, Woods, & Hursh, 1996), although results

inconsistent with unit price also have been noted (Nader & Woolverton, 1991).

The present findings have implications for the direct effects versus the satiation interpretation of drug self-administration at high doses. A direct effects account holds that the self-administered drug decreases response rates under single schedules in a manner similar to the rate-decreasing effects of experimenter-imposed presession administration of drug (e.g., Katz, 1989). An inverse relation between drug dose and response rate is considered to be indicative of direct effects. Direct effects are invoked in part to explain the absence of expected effects under single schedules of drug reinforcement: namely, that as reinforcer magnitude increases, response rate and other measures of reinforcing efficacy should also increase, but instead, they decrease when high doses are available. Conversely, under concurrent schedules, high doses are preferred over lower doses even when the high dose is on the descending limb of the dose–effect function for the single schedule. As such, the direct effects interpretation has emphasized differences between single and concurrent schedules of reinforcement.

Conversely, a behavioral economic perspective suggests that consumption under both single and concurrent schedules is affected by satiation at higher doses. This account is illustrated in Figure 7. The upper left graph shows a hypothetical dose–response curve, and the upper right graph shows the drug intake maintained at these doses. The lower row of graphs shows the same behavioral data plotted as a function of unit price (note that dose and price are inversely related as defined by unit price, assuming a constant response requirement). Although response rates are decreasing along the descending limb of the dose–response function (A), total drug intake is increasing toward an asymptote. In behavioral economic terms, this portion of the demand function (labeled A in the lower left panel of Figure 7) illustrates *inelastic demand*; that is, price increases cause the consumer to increase response output, which results in decreases in consumption that are proportionally smaller than the increases in price. At some increase in unit price, response rates

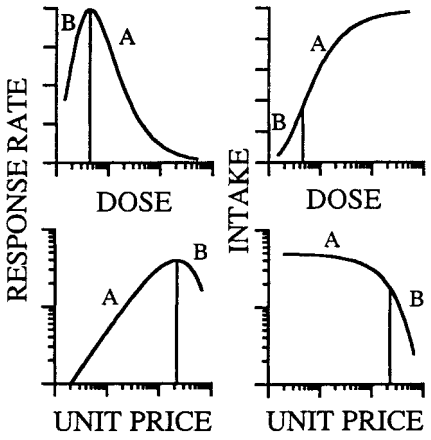

Fig. 7. Hypothetical dose–response curve (upper left), dose–consumption curve (upper right), price–response function (lower left), and demand curve (lower right). These graphs illustrate the relation between response rates and consumption under ratio requirements and the relation between dose and unit price. Note that A and B label positions of the curve that represent inelastic and elastic demand, respectively.

begin to decrease and demand is said to shift to *elastic demand* (B).

In the present experiments, doses were selected that fell along the descending limb of individual subjects' dose–response curves (A in the upper left panel of Figure 7). This portion of the dose–response curve corresponds with the inelastic portion of the demand curve (A in the lower left panel of Figure 7). At these doses, unit price manipulations tended to affect response rate and drug intake in a manner similar to the patterns presented in Figure 7, regardless of the schedule type (single or concurrent chains). This occurred despite the fact that cigarette smoking at the levels maintained in the present experiments in nicotine-dependent subjects tends not to produce direct effects that might decrease response rates (Henningfield, 1984). Indeed, response-rate and demand functions of nonhuman food-maintained behavior typically conform to the patterns presented in Figure 7 as well (e.g., DeGrandpre et al., 1993; Hursh et al., 1988; cf. Goldberg, 1973). The similarity between food- and drug-maintained behavior is interesting because large-magnitude food reinforcers decrease response rates as a function of satiation rather than direct effects. Together these data suggest that satiation may play a role in the response-rate dec-

rements observed along the descending limb of the dose–response function.

Although the findings of the present experiments are consistent with a behavioral economics account, they need not be inconsistent with a direct effects account. The direct effects interpretation could be extended to address these results by noting that direct effects are a result of total drug load independent of source. Thus, these experiments cannot prove the exclusive validity of the different perspectives. Unless a crucial experiment is proposed, neither approach can be rendered invalid. They will just function as different interpretations of the same data generated in the drug self-administration laboratory. However, one or the other of these approaches may be found to pertain to a broader array of data, or suggest a greater number of new and fruitful empirical investigations. The more useful approach (i.e., the pragmatic criterion of truth promulgated by Pierce, James, Dewey, and Skinner; see Zuriff, 1980) may become the one with which students of drug self-administration will have daily commerce. In that regard, we note that the behavioral economic perspective set the occasion for the present study (cf. Bickel, Madden, & Petry, 1998). However, before these results are evaluated vis-à-vis these two interpretations, the generality of the findings remains to be determined. For example, we used FR schedules with cigarette smokers. Whether similar results would be obtained with other schedules of reinforcement and other reinforcers remains to be determined (cf. Bickel, DeGrandpre, & Higgins, 1995; Johanson, Schuster, & Woolverton, 1996).

REFERENCES

Balster, R. L., & Schuster, C. R. (1973). Fixed-interval schedule of cocaine reinforcement: Effect of dose and infusion duration. *Journal of the Experimental Analysis of Behavior, 20,* 119–129.

Baron, A., Kaufman, A., & Stauber, K. A. (1969). Effects of instructions and reinforcement-feedback on human operant behaivor maintained by fixed-interval reinforcement. *Journal of the Experimental Analysis of Behavior, 12,* 701–712.

Bickel, W. K., DeGrandpre, R. J., & Higgins, S. T. (1995). The behavioral economics of concurrent drug reinforcers: A review and reanalysis of drug self-administration research. *Psychopharmacology, 118,* 250–259.

Bickel, W. K., DeGrandpre, R. J., Higgins, S. T., & Hughes, J. R. (1990). Behavioral economics of drug self-administration. I. Functional equivalence of response requirement and drug dose. *Life Science, 47,* 1501–1510.

Bickel, W. K., DeGrandpre, R. J., Higgins, S. T., Hughes, J. R., & Badger, G. J. (1995). Effects of simulated employment and recreation on drug taking: A behavioral economic analysis. *Experimental and Clinical Psychopharmacology, 3,* 467–476.

Bickel, W. K., DeGrandpre, R. J., Hughes, J. R., & Higgins, S. T. (1991). Behavioral economics of drug self-administration. II. A unit-price analysis of cigarette smoking. *Journal of the Experimental Analysis of Behavior, 55,* 145–154.

Bickel, W. K., Hughes, J. R., DeGrandpre, R. J., Higgins, S. T., & Rizutto, P. (1992). Behavioral economics of drug self-administration. IV. The effects of response requirement on the consumption and interaction between concurrently available coffee and cigarettes. *Psychopharmacology, 107,* 211–216.

Bickel, W. K., Madden, G. J., & Petry, N. M. (1998). The price of change: The behavioral economics of drug dependence. *Behavior Therapy, 29,* 545–565.

Carroll, M. E. (1991). Concurrent phencyclidine and saccharin access: Presentation of an alternative reinforcer reduces drug intake. *Journal of the Experimental Analysis of Behavior, 43,* 131–144.

Carroll, M. E., & Bickel, W. K. (1998). Behavioral-environmental determinants of the reinforcing effects of cocaine. In S. T. Higgins & J. L. Katz (Eds.), *Cocaine abuse research: Pharmacology, behavior, and clinical applications* (pp. 81–106). San Diego, CA: Academic Press.

Catania, A. C. (1968). Glossary. In A. C. Catania (Ed.), *Contemporary research in operant behavior* (pp. 327–349). Glenview, IL: Scott Foresman.

DeGrandpre, R. J., Bickel, W. K., Hughes, J. R., Layng, M., & Badger, G. (1993). Unit price as a useful metric in analyzing effects of reinforcer magnitude. *Journal of the Experimental Analysis of Behavior, 60,* 641–666.

Fagerström, K. O., & Schneider, N. G. (1989). Measuring nicotine dependence: A review of the Fagerström tolerance questionnaire. *Journal of Behavioral Medicine, 12,* 159–182.

Galizio, M. (1979). Contingency-shaped and rule governed behavior: Instructional control of human loss avoidance. *Journal of Experimental Analysis of Behavior, 31,* 53–70.

Goldberg, S. R. (1973). Comparable behavior maintained under fixed-ratio and second-order schedules of food presentation, cocaine injection or *d*-amphetamine injection in the squirrel monkey. *Journal of Pharmacology and Experimental Therapeutics, 186,* 18–30.

Griffiths, R. R., Brady, J. V., & Bradford, L. D. (1979). Predicting the abuse liability of drugs and animal drug self-administration procedures: Psychomotor stimulants and hallucinogens. In T. Thompson & P. B. Dews (Eds.), *Advances in behavioral pharmacology* (pp. 163–208). New York: Academic Press.

Henningfield, J. E. (1984). Behavioral pharmacology of cigarette smoking. In T. Thompson, P. B. Dews, & J. E. Barrett (Eds.), *Advances in behavioral pharmacology* (pp. 131–210). Orlando, FL: Academic Press.

Henningfield, J. E., & Griffiths, R. R. (1981). Cigarette smoking and subjective response: Effects of *d*-amphetamine. *Clinical Pharmacology and Therapeutics, 30,* 497–505.

Henningfield, J. E., Stitzer, M. L., & Griffiths, R. R. (1980). Expired air carbon monoxide accumulation and elimination as a function of number of cigarettes smoked. *Addictive Behaviors, 5,* 265–272.

Hursh, S. R., Raslear, T. G., Shurtleff, D., Bauman, R., & Simmons, L. (1988). A cost-benefit analysis of demand for food. *Journal of the Experimental Analysis of Behavior, 50,* 419–440.

Johanson, C. E. (1975). Pharmacological and environmental variables affecting drug preference in rhesus monkeys. *Pharmacological Reviews, 27,* 343–355.

Johanson, C. E., & Schuster, C. R. (1975). A choice procedure for drug reinforcers: Cocaine and methylphenidate in the rhesus monkey. *Journal of Pharmacology and Experimental Therapeutics, 193,* 676–688.

Johanson, C. E., Schuster, C. R., & Woolverton, W. L. (1996). The role of behavioral economics in the behavioral pharmacology of drug abuse: A commentary. In L. Green & J. H. Kagel (Eds.), *Advances in behavioral economics: Vol. 3. Substance use and abuse* (pp. 96–106). Norwood, NJ: Ablex.

Katz, J. L. (1989). Drugs as reinforcers: Pharmacological and behavioural factors. In J. M. Liebman & S. J. Cooper (Eds.), *The neuropharmacological basis of reward* (pp. 164–213). New York: Oxford University Press.

Logue, A. W., & Chavarro, A. (1987). Effect on choice of absolute and relative values of reinforcer delay, amount, and frequency. *Journal of Experimental Psychology: Animal Behavior Processes, 13(3),* 280–291.

Nader, M. A., & Woolverton, W. L. (1991). Effects of increasing the magnitude of an alternative reinforcer on drug choice in a discrete-trials choice procedure. *Psychopharmacology, 105,* 69–174.

Pearce, D. W. (Ed.). (1989). *The MIT dictionary of modern economics* (3rd ed.). Cambridge, MA: MIT Press.

Raslear, T. G., Bauman, R. A., Hursh, S. R., Shurtleff, D., & Simmons, L. (1988). Rapid demand curves for behavioral economics. *Animal Learning and Behavior, 16,* 330–339.

Samuelson, P. A., & Nordhaus, W. D. (1985). *Economics* (12th ed.). New York: McGraw-Hill.

Skjoldager, P., Winger, G., & Woods, J. H. (1991). Analysis of fixed-ratio behavior maintained by drug reinforcers. *Journal of the Experimental Analysis of Behavior, 56,* 331–343.

Spealman, R. D., & Goldberg, S. R. (1978). Drug self-administration in laboratory animals: Control by schedules of reinforcement. *Annual Review of Pharmacology and Toxicology, 18,* 313–339.

Williams, B. A. (1984). Stimulus control and associative learning. *Journal of the Experimental Analysis of Behavior, 42,* 469–483.

Winger, G. (1993). Fixed-ratio and time-out changes on behavior maintained by cocaine or methohexital in rhesus monkeys: 2. Behavioral economic analysis. *Experimental and Clinical Psychology, 1,* 154–161.

Winger, G., Woods, J., & Hursh, S. R. (1996). Behavior maintained by alfentanil or nalbuphine in rhesus monkeys: Fixed-ratio and time-out changes to establish demand curves and relative reinforcing effectiveness. *Experimental and Clinical Psychopharmacology, 4,* 131–140.

Zacny, J. P., Stitzer, M. L., Brown, F. J., Yingling, J. E., & Griffiths, R. R. (1987). Human cigarette smoking: Effects of puff inhalation parameters on smoke exposure. *Journal of Pharmacology and Experimental Therapeutics, 240,* 554–564.

Zuriff, G. E. (1980). Radical behaviorist epistemology. *Psychological Bulletin, 87,* 337–350.

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APPENDIX

Consent Form
Human Drug Self-Administration Study

Introduction

You are invited to participate in a research study. The purpose of the study is to help understand why people smoke cigarettes in the patterns that they do. This study is funded by the National Institute on Drug Abuse.

Procedures

Study participation is for a period of approximately 10–14 weeks, at the discretion of the director of the laboratory. Although you are agreeing to participate for up to 10–14 weeks, sometimes we learn all we can from a participant in one or two sessions.

During the study you will report to a research facility 5 times per week at the same time each day. The first session will be a training session in which you will become familiar with the procedures. All experimental sessions will be 3.5 hours long. During the sessions, you will work (pull one or more levers) for the opportunity to smoke cigarettes or earn other consequences. The amount of work required to obtain the cigarettes and the number of puffs that can be obtained will change during your participation in the study. During the sessions, you will be free to choose to smoke cigarettes according to your own preferences. You will also be asked to fill our questionnaires about your mood before and after each session.

Presession

As a participant, you will be required to abstain from cigarette smoking for 5–6 hours before each session so that you may provide a carbon monoxide "breath" reading (a measure of cigarette use) that is ½ of the original value obtained during your initial interview. Also you must not drink alcoholic beverages

for 12 hours prior to each session. Alcohol consumption will be measured daily with an electronic breath test. You must not use illicit drugs at *any time* during the study (this includes your free time outside the laboratory). Drug use may be screened through an analysis of your urine at random times during the study. Finally, it is important for the validity of the study that you eat approximately the same amount of food and drink about the same amount of caffeinated beverages before each session. If presession screening tests reveal that you have smoked too much or have consumed alcohol before the session, you will be released for the day without pay. Should this become a recurring problem, your participation will be discontinued. If tests reveal that you have used illicit drugs during the dates of your participation, your participation will be discontinued. The experimenters also retain the right to discontinue your participation in the study, if, in their judgment, continued participation would put you in physical or psychological danger.

Benefits

There will be no cost incurred by you for participating in the study. You will receive monetary reimbursement for the time you participate in the study at a rate of $17.50 per session. You will receive $20.00 for undergoing the initial interview. In addition, if you complete the entire study, you will receive a bonus of $17.50 per session. All money will be held in reserve until either the study is completed, you choose to withdraw from the study, or your participation in the study is terminated. If you require money to cover travel, babysitting, etc., expenses, you may draw up to $10 per session from your cumulating compensation. This money will be given after the last scheduled session of the week and only if you have attended all scheduled sessions that week.

If you do not complete the study, you DO NOT forfeit any money earned over the course of the study. The full amount owed to you will be paid after the date scheduled for your final session had you completed the study. Note, however, that if you withdraw from the experiment before it has concluded, then you forfeit the $17.50 per session bonus money you would have earned had you completed the experiment.

Should your participation in the study be discontinued by the laboratory director for failing to comply with any requirements listed in this consent form, you will forfeit the $17.50 per session bonus money.

You will not receive any direct benefits from these studies. However, the knowledge gained may result in a better understanding of the behavioral and psychological effects of cigarettes and may help improve treatment.

Requirements for Participation

In order to be eligible to participate in this study, you must be in good physical and psychiatric health as indicated by medical and psychiatric screenings. Any evidence that you have a health problem, a psychiatric condition, drug or alcohol abuse will preclude your participation in this research project. Pregnant or lactating women are excluded from participation in this study. Please advise us if you become pregnant during the study; your participation may then be discontinued without forfeiting your $17.50 per session bonus pay.

Risks

The risks associated with this research are the normal risks associated with smoking cigarettes. Additionally, you may feel nicotine intoxication or withdrawal symptoms (e.g., dizziness, increased heart rate, headache, irritability, sleepiness, decreased alertness, difficulty concentrating, impatience, sleeplessness, and increased eating) from refraining from cigarettes. Given the modest period of abstinence required and small amounts of cigarettes that can be earned, we believe significant symptoms are unlikely and have not been encountered in our prior research.

It is not the policy of the University of Vermont (and/or Fletcher Allen Health Care) to provide payment or free medical treatment in the event of injury resulting from this research.

Voluntary Participation

Your participation is voluntary. You may decide to withdraw at any time without forfeiting any earnings. Further, withdrawing from the study will not prejudice our subsequent interactions with you. Withdrawing from the

experiment before its completion will result in your forfeit of all bonus money.

Confidentiality

All information that you provide is strictly confidential. Your identity on the records relevant to this study will not be made public. Any publications resulting from this research will not mention your name.

Contact Persons

[This paragraph gave the names and phone numbers of people to call for more information about the study.]

Agreement

You are making a decision about whether or not to participate in a medical research study. Your signature below indicates that you have read the information and have decided to participate. Further, your signature below affirms that (1) you understand the purpose, procedures, benefits, potential risks, and voluntary nature of the study; (2) you have been given the opportunity to ask questions about the study and have received comprehensible answers; and (3) you know who to contact should you have additional questions about the research or your rights as a participant.